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Kneedler

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(54) **DISTRIBUTED POTENTIAL CHARGED PARTICLE DETECTOR**

(75) Inventor: **Eric Kneedler**, Portland, OR (US)

(73) Assignee: **FEI Company**, Hillsboro, OR (US)

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G21K 5/04 (2006.01)

(52) **U.S. Cl.**
USPC .... **250/397**; 250/396 R; 250/398

(58) **Field of Classification Search**
USPC .... 250/306, 307, 309, 310, 311, 396 R, 250/397, 398, 396 ML
See application file for complete search history.

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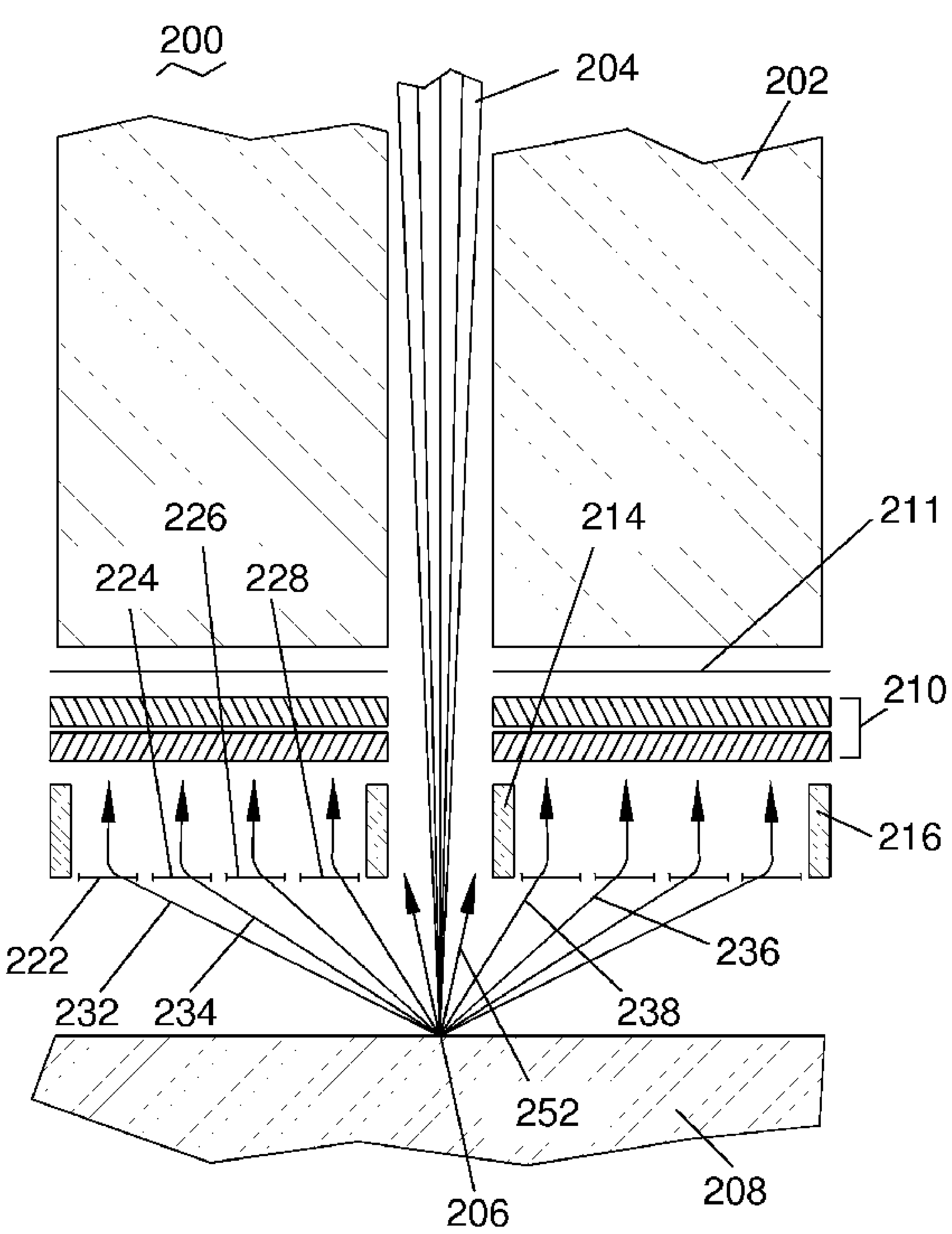
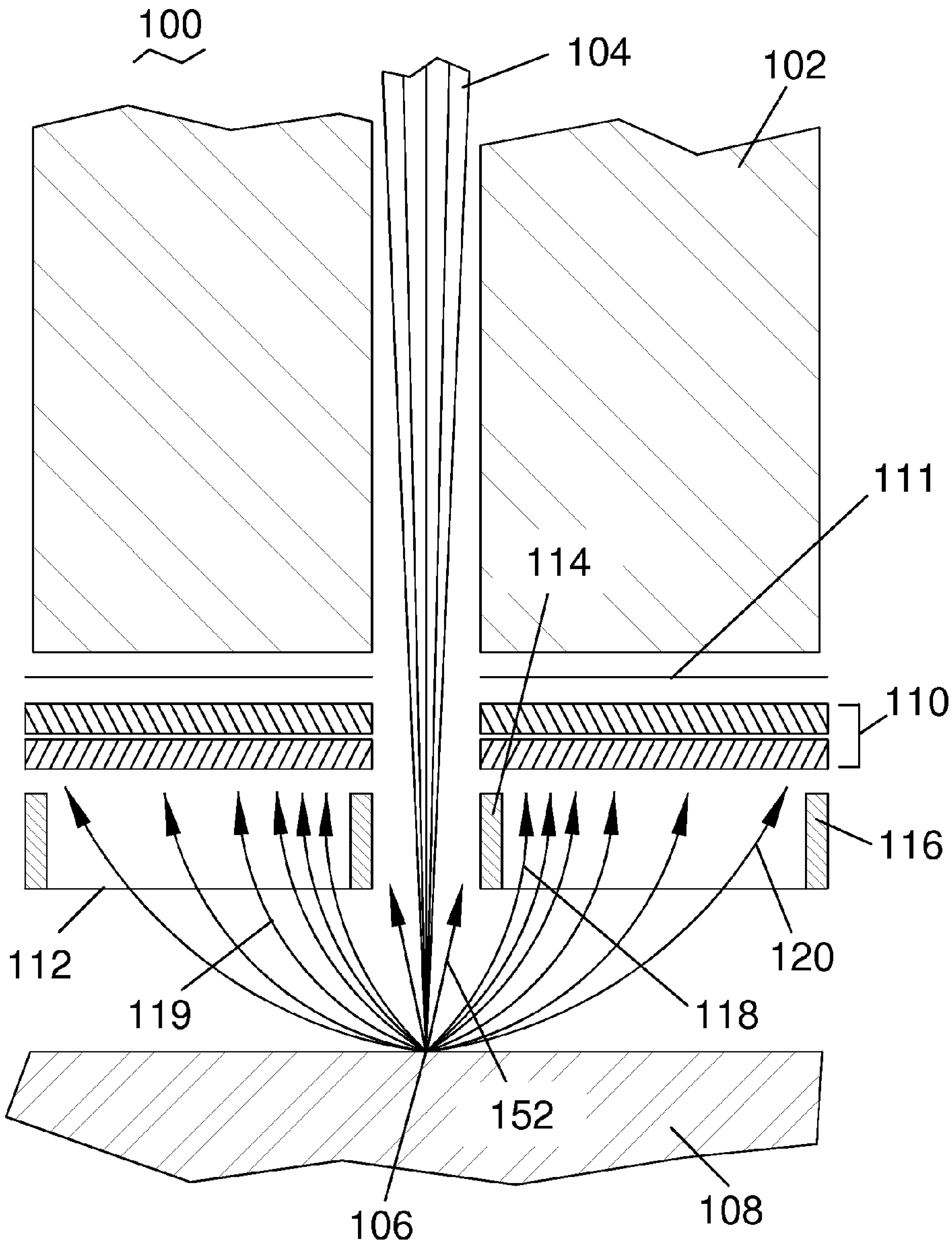
Primary Examiner — Nicole Ippolito
(74) *Attorney, Agent, or Firm* — Scheinberg & Associates, PC; Michael O. Scheinberg

(57) **ABSTRACT**

A charged particle beam system for imaging and processing targets is disclosed, comprising a charged particle column, a secondary particle detector, and a secondary particle detection grid assembly between the target and detector. In one embodiment, the grid assembly comprises a multiplicity of grids, each with a separate bias voltage, wherein the electric field between the target and the grids may be adjusted using the grid voltages to optimize the spatial distribution of secondary particles reaching the detector. Since detector lifetime is determined by the total dose accumulated at the area on the detector receiving the largest dose, detector lifetime can be increased by making the dose into the detector more spatially uniform. A single resistive grid assembly with a radial voltage gradient may replace the separate grids. A multiplicity of deflector electrodes may be located between the target and grid to enhance shaping of the electric field.

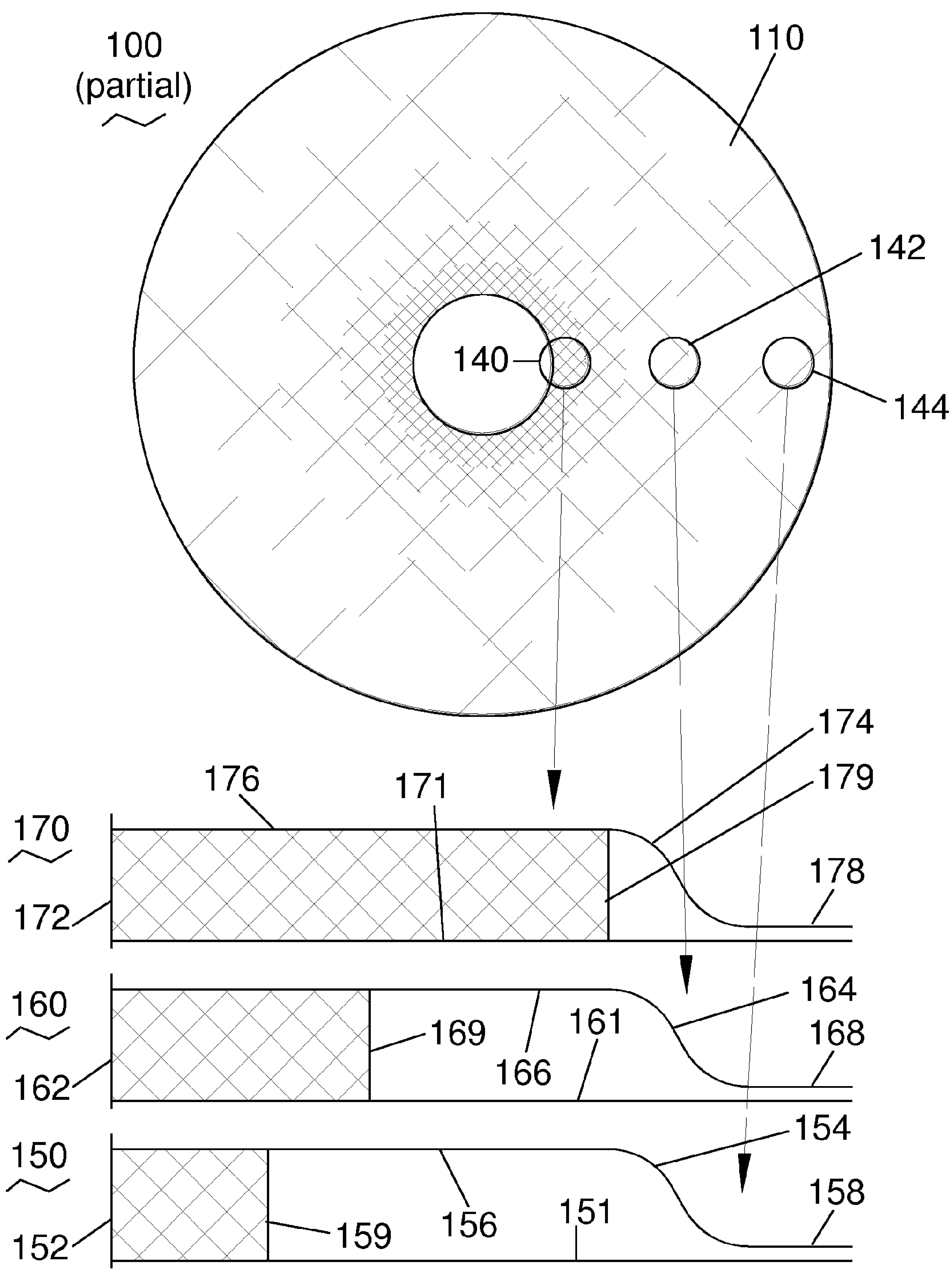
22 Claims, 12 Drawing Sheets





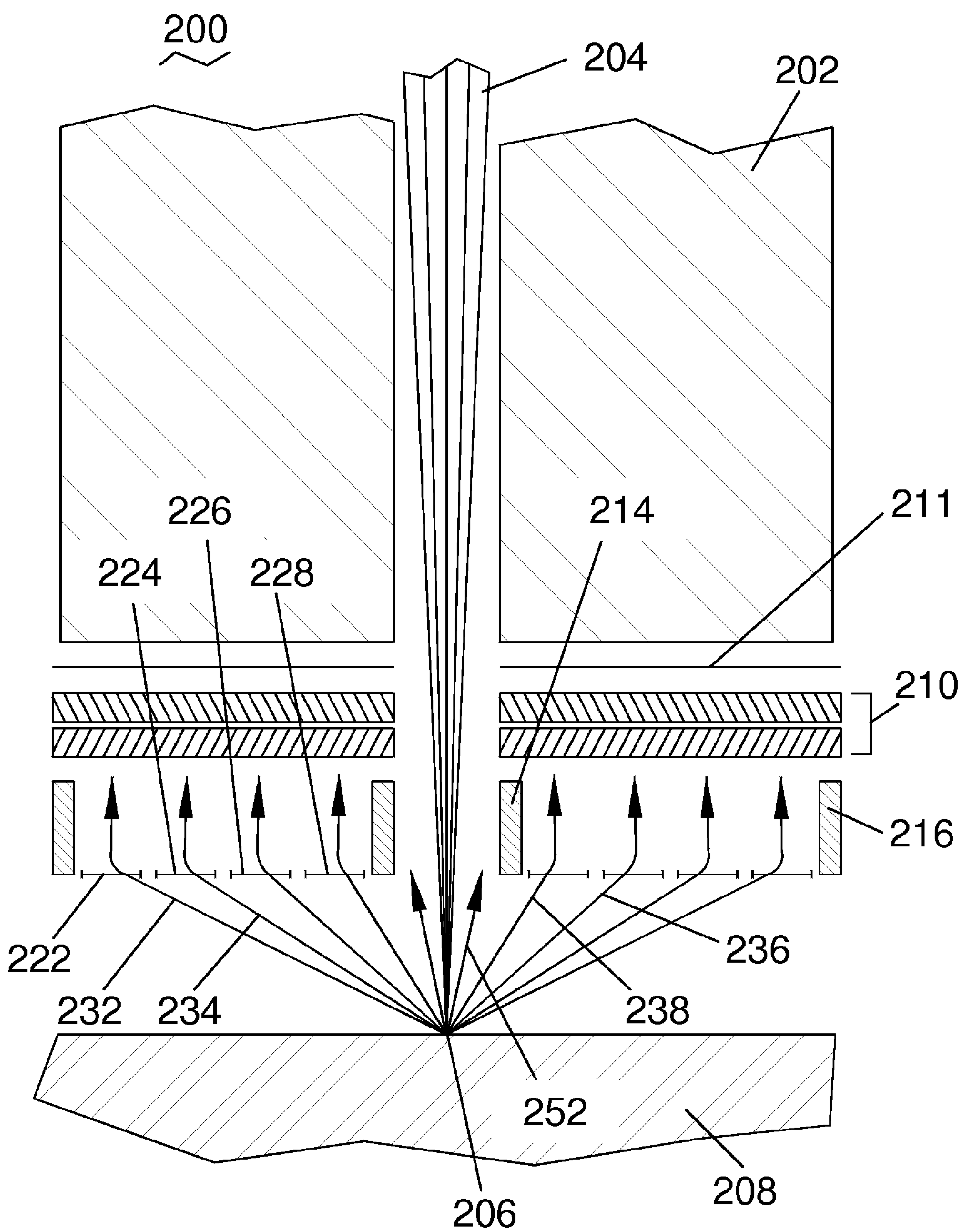
PRIOR ART

FIG. 1A



PRIOR ART

FIG. 1B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202
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214
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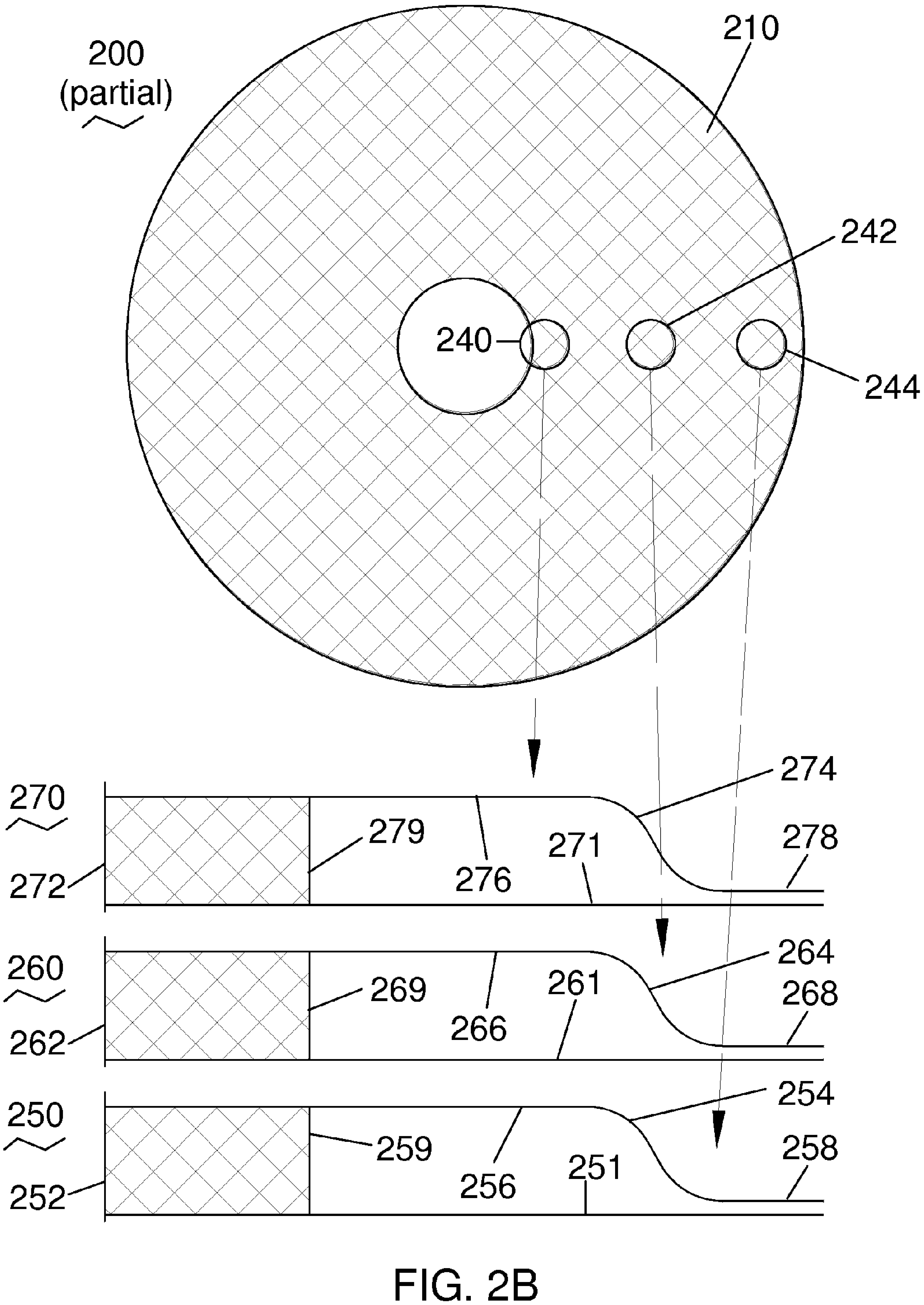
208

FIG. 2A



200
(partial)
210
242
240
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254
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251
252
256

FIG. 2B

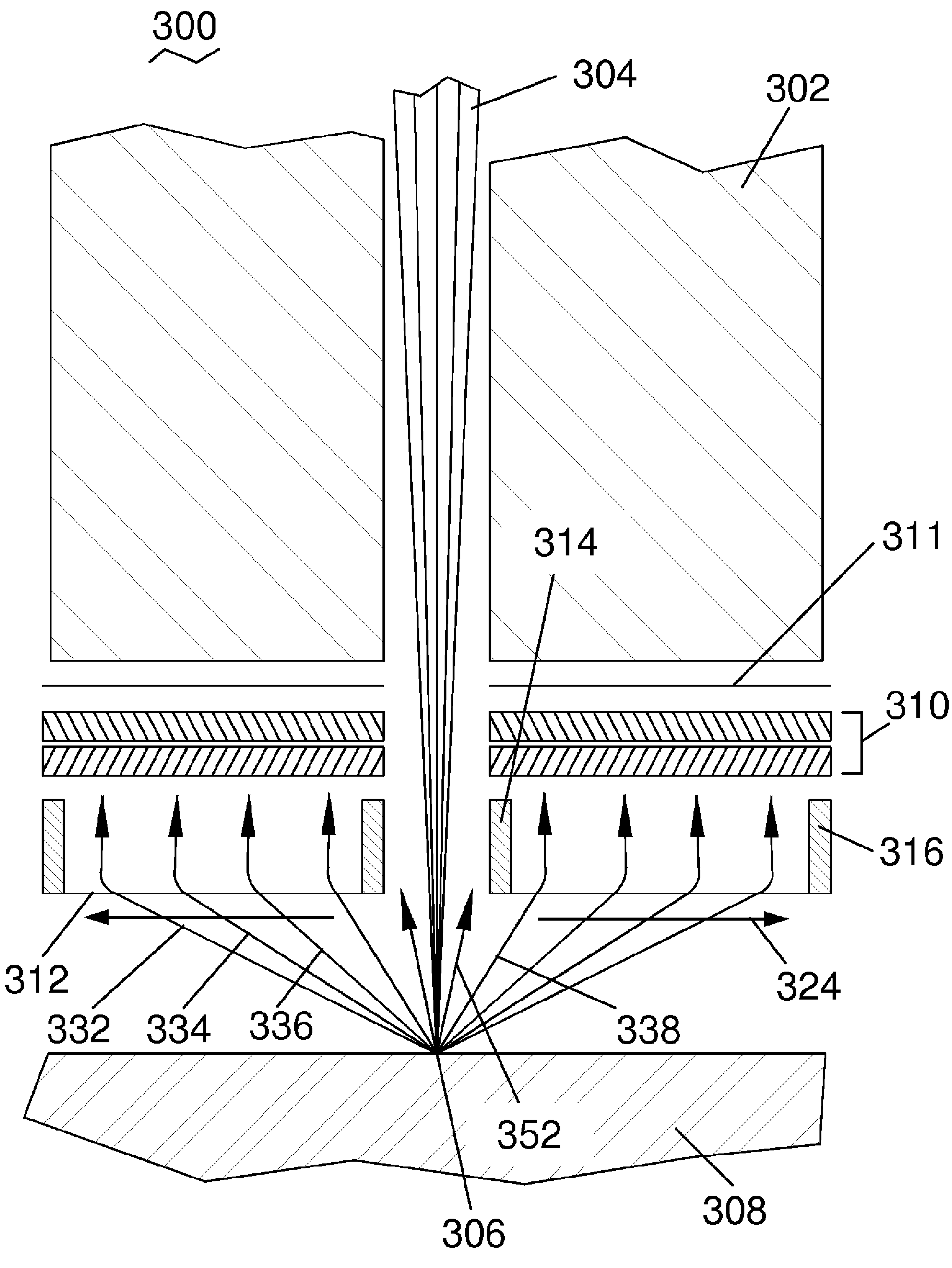
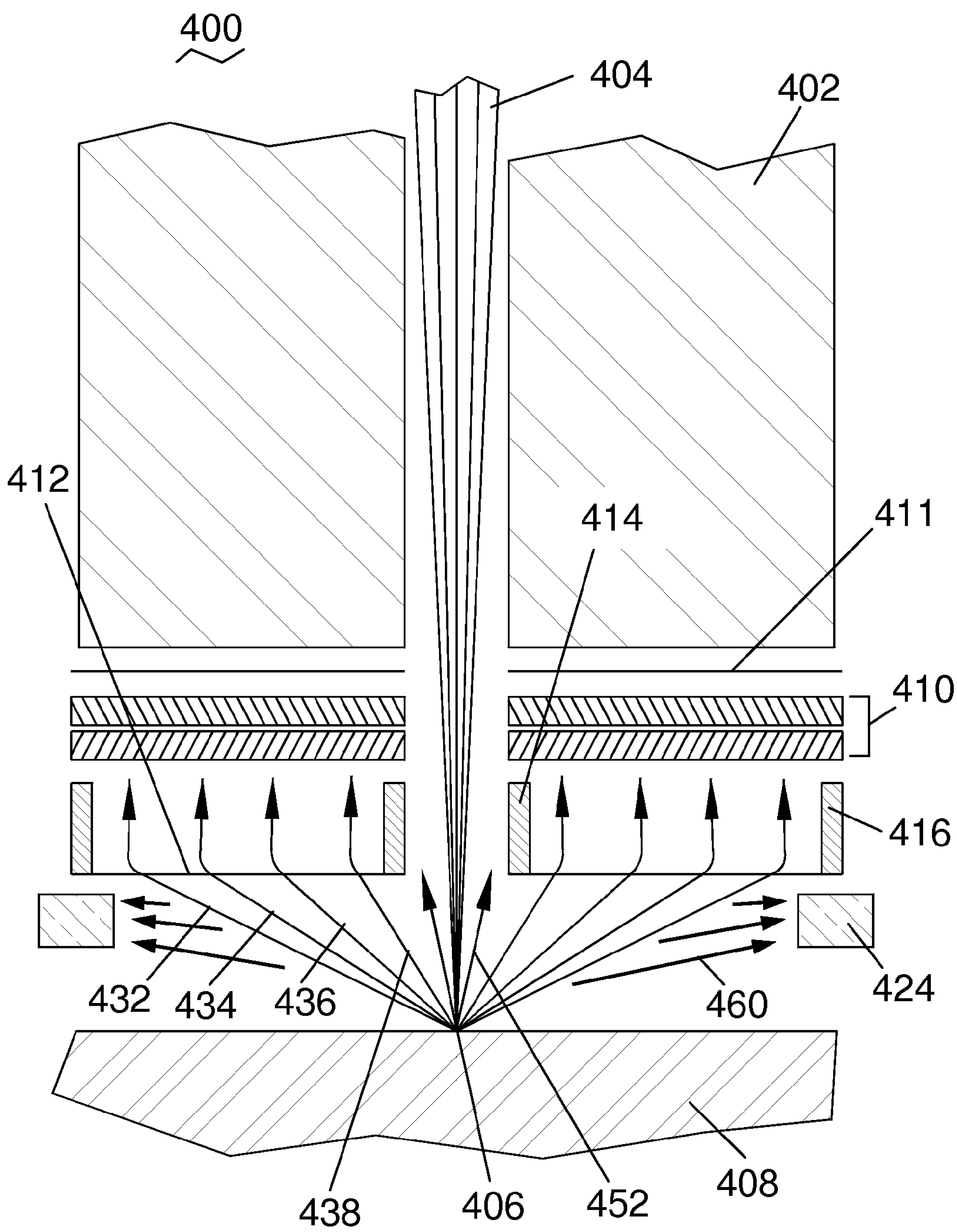


FIG. 3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452
408

FIG. 4

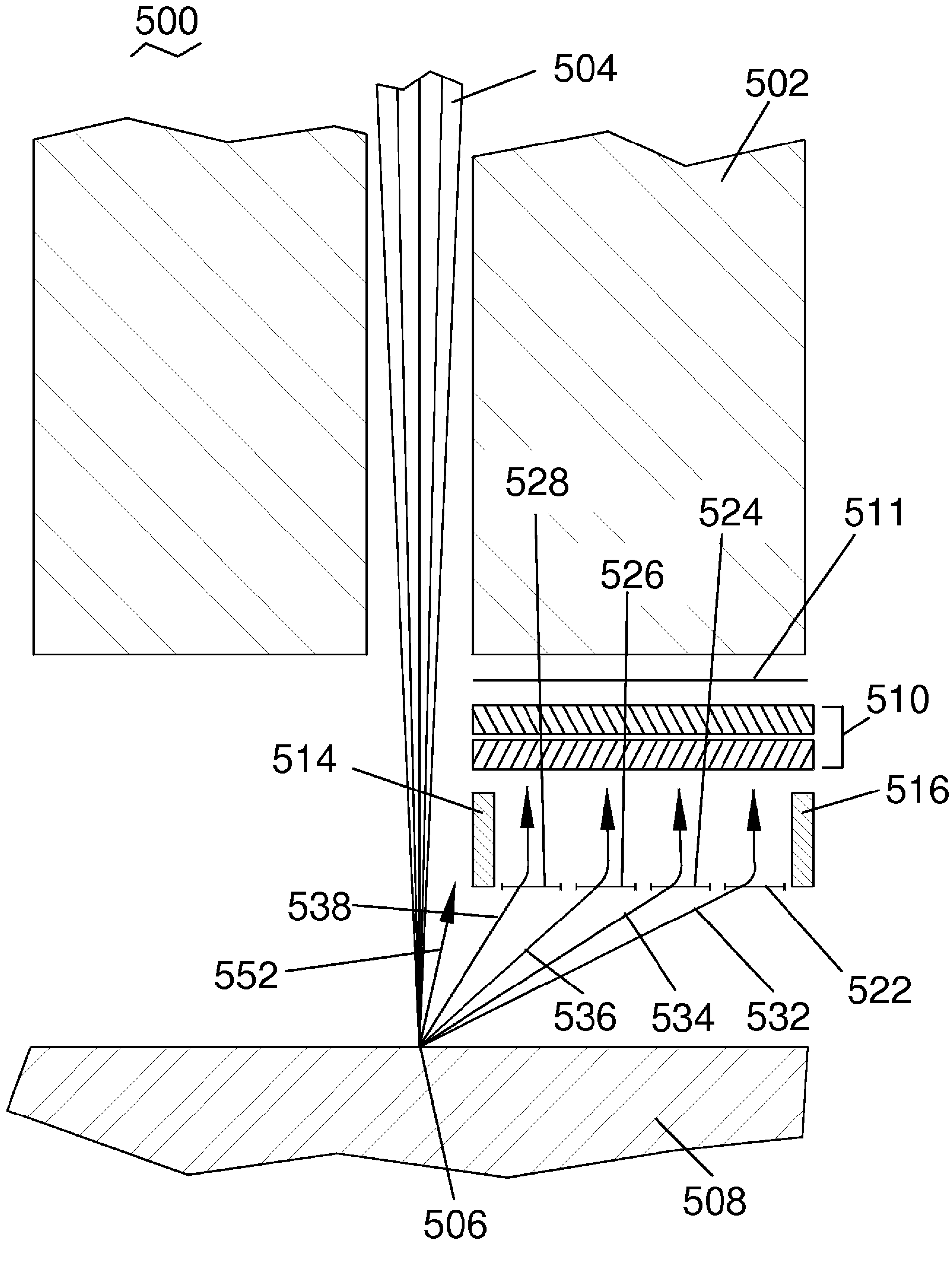
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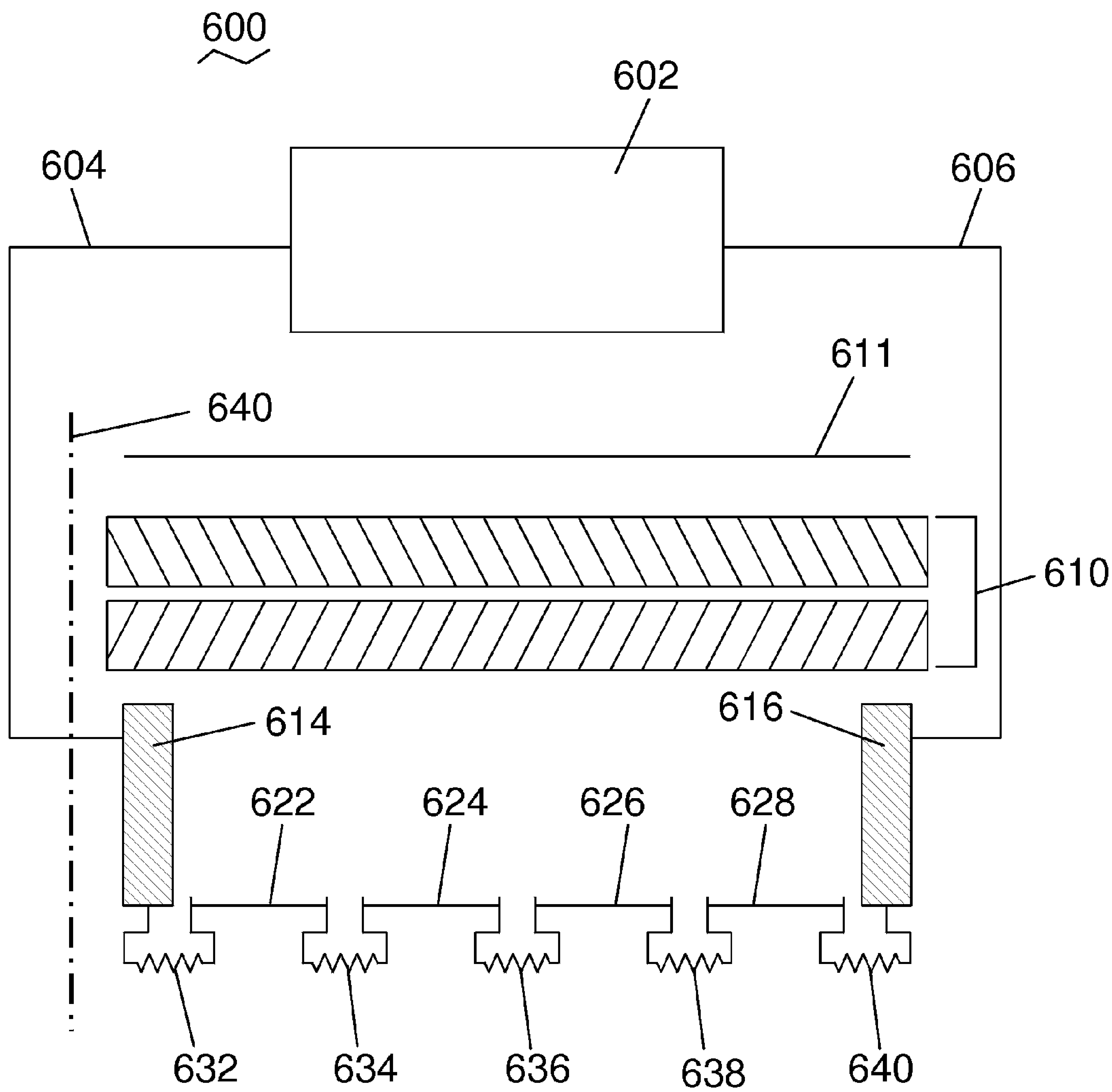
FIG. 5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602
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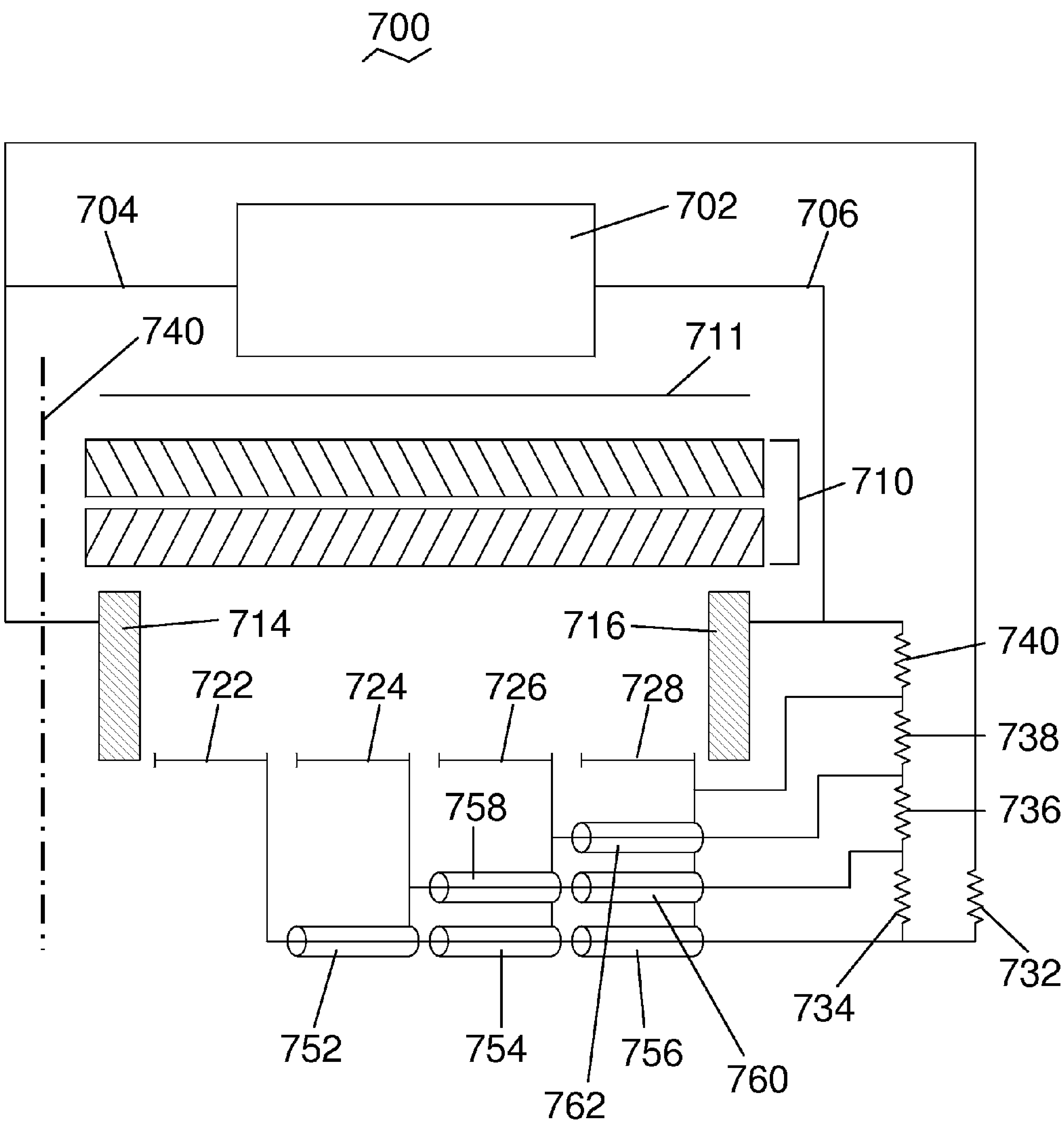
636
638
640

FIG. 6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704
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706
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711
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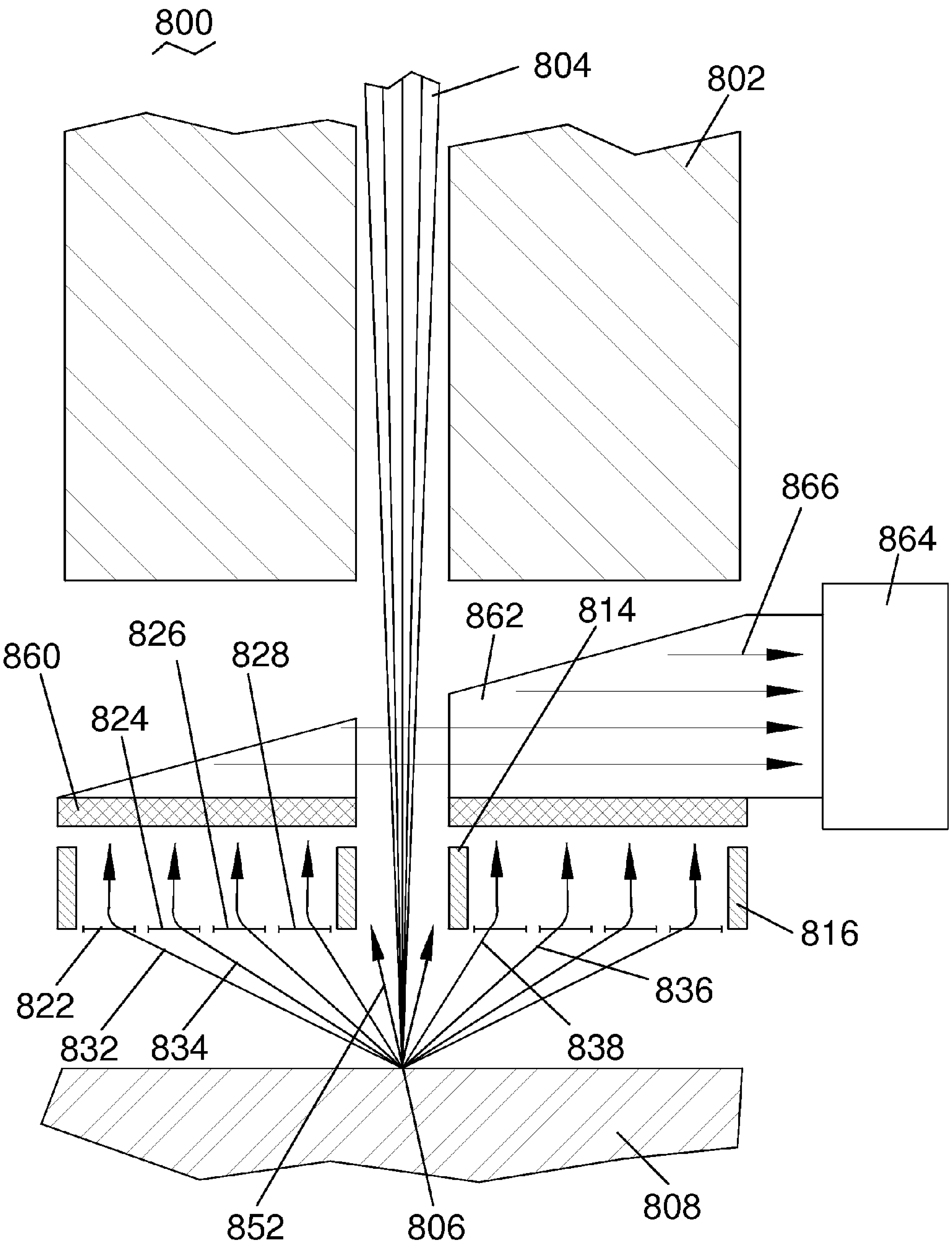
762
760
734
732

FIG. 7


800
804
802
866
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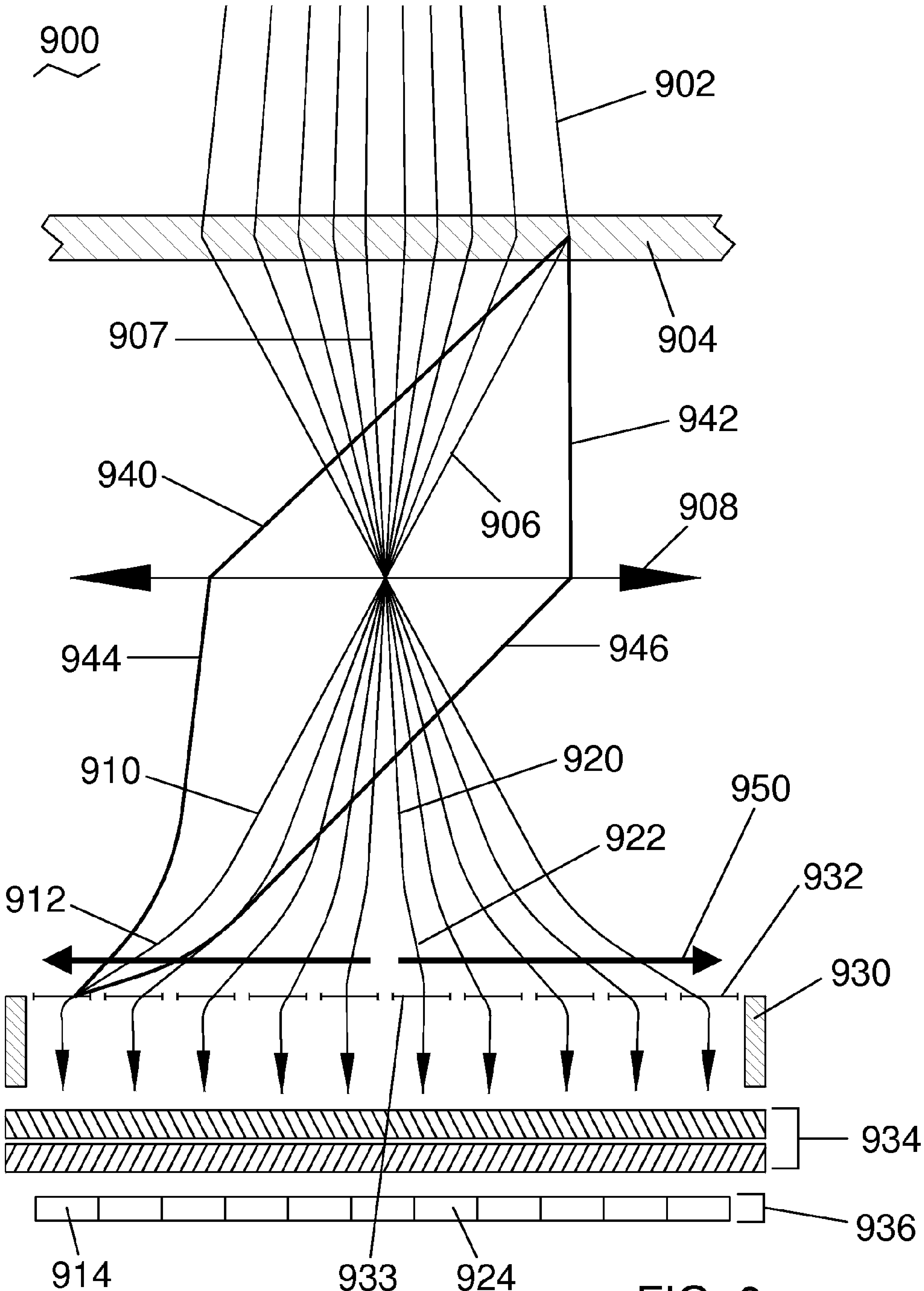
828
860
824
816
836
822
832
834
838
852
806
808

FIG. 8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942
940
906
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912
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924

FIG. 9

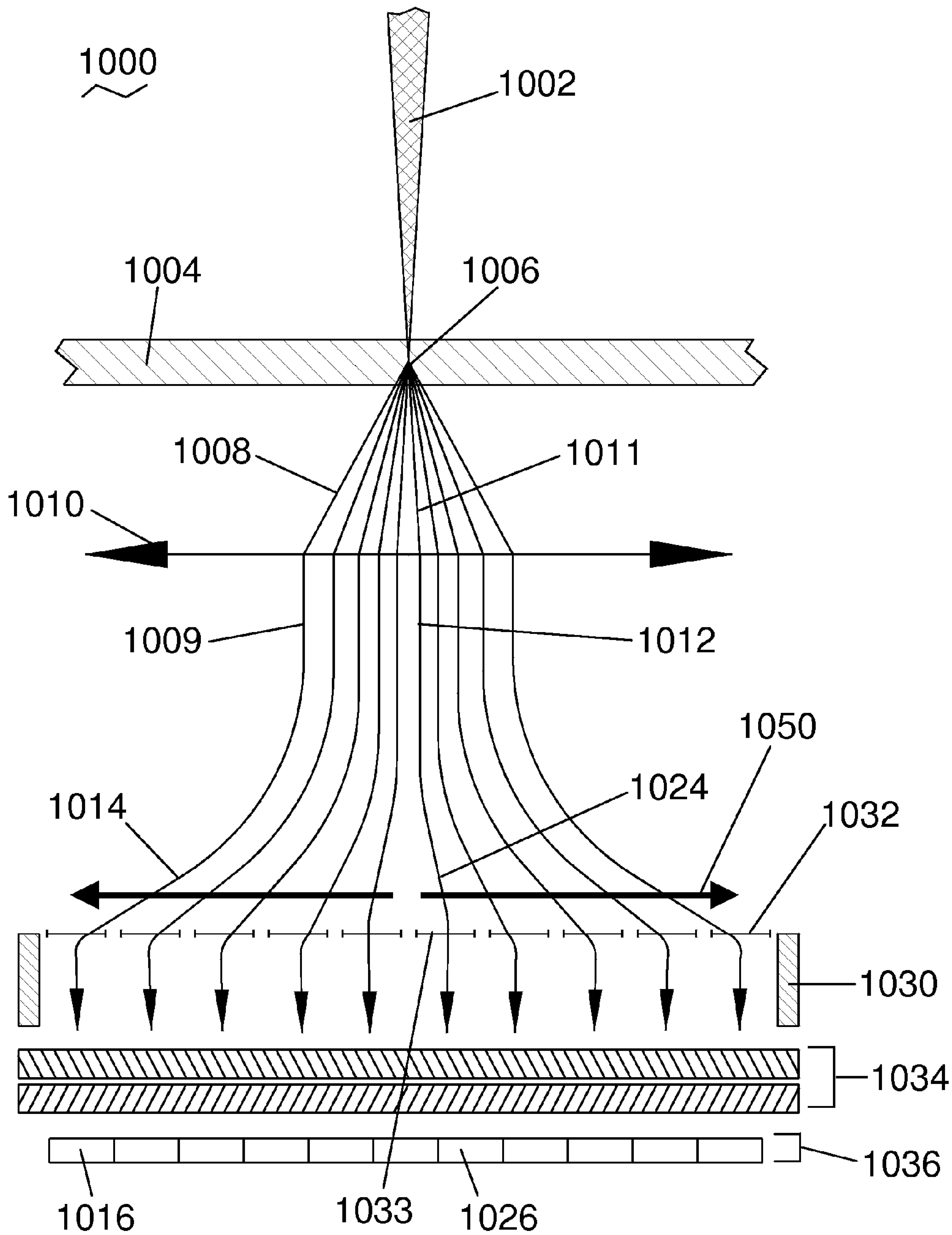
1000
1002
1004
1006
1008
1011
1010
1009
1012
1050
1014
1024
1032
1030
1034
1036
1016
1033
1026

FIG. 10

DISTRIBUTED POTENTIAL CHARGED PARTICLE DETECTOR

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to focused charged particle systems and in particular to reducing damage and contamination in detectors for secondary particles.

BACKGROUND OF THE INVENTION

In charged particle systems, comprising both electron microscopes and focused ion beam systems, a column is typically used to focus a charged particle beam onto the surface of a target to be imaged and (optionally) processed using the beam. To form an image of the target, it is necessary to deflect the beam across the target surface, usually in a raster pattern. Due to the impact of the charged particle beam with the target, secondary particles are emitted and may be collected to form an imaging signal. As an example, an electron beam will stimulate the emission of secondary electrons from the target. A focused ion beam will stimulate the emission of both secondary electrons and secondary ions (usually positively-charged). A secondary particle detector is employed in these systems to generate the necessary imaging signal—these detectors may be characterized by their collection efficiency, i.e., the fraction of emitted secondary particles which are actually collected by the detector. To enhance this collection efficiency, a "collection" grid is often positioned between the target and the detector. A voltage applied to this grid creates an electric field between the target and grid to attract secondary particles, which then pass through the grid (a sparse mesh or other nearly transparent structure) and then to the detector.

Unfortunately, it is found that over time, secondary detectors may exhibit a loss in efficiency due to either damage to the detector and/or a build-up of contamination on the detector surface. This damage results from the energetic bombardment of the detector by incoming secondary particles, which can disrupt the detector material. Contamination covers the detector with a thin film such as polymerized hydrocarbons arising from the interaction of the charged particle beam with trace gases in the vacuum system—often these gases arise from the interaction of the charged particle beam with the target, and thus are difficult to avoid even in systems with very low base pressures. Typically this damage is non-uniform over the detector surface. This non-uniformity arises because the emission pattern of secondary particles from the target is concentrated in a direction upwards (following a cosine law) from the target. If the detector is an annulus surrounding the primary charged particle beam, then the majority of the collected secondary particles will strike the detector near the center. Thus, the accumulated damage and/or contamination on the detector will also be concentrated near the center. Detector lifetime is determined by the most damaged or contaminated area (even if the majority of the detector area is still functional), so when the center of the detector becomes unusable due to damage and/or contamination, the entire detector must be replaced, reconditioned, or cleaned. Thus, it would be advantageous in charged particle systems to improve the detector lifetime by making the damage and/or contamination rate more uniform over the area of a charged particle detector to improve the overall detector lifetime.

SUMMARY OF THE INVENTION

An object of the invention is to improve the lifetime of secondary particle detectors in charged particle systems.

The present invention increases the useful life of secondary particle detectors by providing a detector assembly that spreads the secondary particles more evenly over the detector, thereby reducing the damage to parts of the detector that would otherwise degrade more quickly because of the disproportionately large number of secondary particles impinging on those portions of the detector. In some embodiments, a grid positioned between the target and the detector provides a field that spreads the secondary particles more evenly over the detector. The grid can comprise multiple sections, each at a different potential, or a resistive grid can provide different potentials across a single grid section.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more thorough understanding of the present invention, and advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1**A shows a prior art charged particle detector in a charged particle system;

FIG. **1**B is a portion of the prior art charged particle detector from FIG. **1**A, showing graphs of the detector gain as a function of the time-integral of the detector output current;

FIG. **2**A shows a first embodiment of the invention, comprising a multiplicity of annular collection grids;

FIG. **2**B is a portion of the first embodiment of the invention from FIG. **1**A, showing graphs of the detector gain as a function of the time-integral of the detector output current;

FIG. **3** shows a second embodiment of the invention, comprising a single resistive annular collection grid;

FIG. **4** shows a third embodiment of the invention, comprising a multiplicity of deflector electrodes for attracting charged particles;

FIG. **5** shows a fourth embodiment of the invention, comprising an off-axis charged particle detector with a multiplicity of collection grids;

FIG. **6** shows an electrical schematic diagram for a first biasing circuit for a multiplicity of grids;

FIG. **7** shows an electrical schematic diagram for a second biasing circuit for a multiplicity of grids;

FIG. **8** shows another version of a first embodiment of the invention, comprising a scintillator, light pipe, and photomultiplier;

FIG. **9** shows another embodiment of the invention, with application to a transmission electron microscope (TEM); and

FIG. **10** shows another embodiment of the invention, with application to a scanning transmission electron microscope (STEM).

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention provides a field that that deflects secondary charged particles before they impact on a detector to reduce the maximum current density of the charged particles impinging on the charged particle detector, thereby prolonging the useful life of the charged particle detector. By "maximum current density" is meant the highest current density on any area of the detector. The distribution of the secondary charged particles is more uniform that it would be in the absence of the provided field.

In one embodiment, the invention positions a multiplicity of secondary particle collection grids between a target and the secondary particle detector. The voltage on each grid is independently controllable in order to create an electric field between the target and the array of collection grids which deflects the secondary particles farther off-axis. This deflection of the secondary particles makes the distribution of secondary particles which reach the detector more spatially uniform that would be the case with a single collection grid. The term "secondary particle" as used herein includes backscattered particles from the primary beam.

In a second embodiment, a resistive grid is used in place of the array of grids. A voltage is applied across the resistive grid to create approximately the same electric field as was induced in the first embodiment using the separate grids.

In a third embodiment, a multiplicity of deflector electrodes is positioned between the collection grid and the target, again with the purpose of creating an electric field needed to make the secondary particle distribution at the detector more uniform.

Embodiments of the present invention may also be used in cases where the detector is used in an imaging mode, as illustrated herein for a transmission electron microscope (TEM—FIG. **9**) and a scanning transmission electron microscope (STEM—FIG. **10**). In these applications, it is often the case that the full detector area cannot be used for imaging due to considerations in the optical designs of the columns. Thus, the particle distributions at the detector are again non-uniform (often more concentrated around the symmetry axis of the column). Embodiments of the present invention may enable more of the detector area (typically areas farther from the symmetry axis of the column) to be used for imaging, thereby increasing the detector lifetime. For these imaging applications, it may not be possible to make the signal current fully uniform at the detector since the spatial distribution of particles striking the detector conveys image information. Positional information is maintained by expanding the secondary charged particle spatial distribution, that is, maintaining the relative position of the secondary particles from the optical axis of the column. An additional benefit for imaging detectors may be an increase in the imaging resolution—this arises from the fact that spreading the imaging signal over a larger area of the detector may enable the use of a larger number of detector elements within the detector array to form the image.

A further benefit of some embodiments of the present invention is the potential for higher signal gains in cases where local saturation of the detector gain would otherwise occur. For example, it is well known that multichannel plates (MCPs) amplify the input signal current by as much as 10^6-10^7—this amplification occurs within the many channels of the MCP. If a large input signal current strikes only a small area of the MCP, it is possible to saturate the local gain that region of the MCP, while other areas of the MCP (receiving lower input currents) still retain their original (higher) gains. This saturation in MCPs occurs due to "current loading" effects in which the inherent resistivity of the MCP prevents enough supply current from reaching the saturated area of the MCP to provide the normal level of signal amplification. Since the present invention spreads the input current over a larger and more uniform area of the detector, these local saturation effects should be reduced or eliminated. This corresponds to a wider range of linearity (i.e., higher gain before saturation) in the overall detector response.

Although those of ordinary skill in the art will readily recognize many alternative embodiments, especially in light of the illustrations provided herein, this detailed description is exemplary of the preferred embodiments of the present invention, the scope of which is limited only by the appended claims.

The present invention derives from the recognition that the lifetime of secondary particle detectors in charged particle systems may be adversely affected by two factors:

1) Damage to the detector due to bombardment by secondary particles, and
2) Contamination of the detector due to polymerization and deposition of materials on the detector arising from bombardment by secondary particles.

Typical types of secondary electron detectors comprise:

1) Multichannel plates (MCPs)—these types of detectors have a large number of very small channels operating in parallel across the collection area of the detector. Each channel operates independently of the others, amplifying the incoming secondary particle current by factors of as much as 10^6-10^7 in a process of cascade multiplication within each channel. This amplified current is then collected on one or more anodes positioned on the far side of the MCP (i.e., the opposite side from the side receiving the input signal current). Often, to avoid "ion feedback", a two-stage structure is employed in which the channels in the first stage have a different angle than those in the second-stage, thereby eliminating "line-of-sight" travel of positive ions from the exit back to the entrance of the MCP.
2) PIN diodes—these types of detectors are essentially a diode within which the incoming secondary particle produces a cascade of electron-hole pairs. The gain of the PIN diode detector is proportional to the energy of the incoming secondary particle.
3) Scintillator+Light Pipe+PMT—this common type of detector operates by the initial generation of light within the scintillator material (typically either a crystal or plastic) due to the impact of a secondary particle. This light is then transmitted through the light pipe to a photomultiplier tube (PMT), usually located outside the vacuum enclosure of the charged particle system comprising the secondary particle detector.

All three of these detectors have this characteristic in common: the entire detector will become unusable if any part of the detector becomes unusable. Since the rates of damage and/or contamination for each specific area of a detector are generally proportional to the integrated total dose of input signal into that specific area, it is clearly advantageous to ensure that all areas of the detector receive similar dose rates to ensure that the detector lifetime is maximized (i.e., the entire detector becomes unusable at approximately the same time). When only a small area of a detector receives a disproportionately large fraction of the overall secondary particle flux, clearly that area will be damaged and/or contaminated more quickly than would be the case if the secondary particle flux were more evenly distributed over the full collection area of the detector. In addition, for MCPs, if a small area of the MCP detector receives a disproportionately large fraction of the input signal current, local gain saturation may occur, resulting in non-linearity across the detector area.

FIG. **1**A shows a prior art charged particle detector **100**, wherein a charged particle column **102** focuses a charged particle beam **104** onto a location **106** on the surface of a target **108**. Due to the impact of the charged particle beam **104** with the target **108**, secondary particles **118**, **119**, **120** and **152** may be emitted from the target. For the case where charged particle beam **104** is an electron beam, these secondary particles will be secondary electrons. For the case where charged particle beam **104** is a focused ion beam (FIB), both secondary electrons and secondary ions (mostly positive) may be emitted from the target **108**. Generally, the emission pattern of secondary particles (in the case of a normally-incident primary beam **104**), tends to follow a Lambert, or cosine, law angular distribution concentrated around an axis perpendicular to the surface of the target **108** at the point **106** of impact of the primary charged particle beam **104** with the target **108**. In the prior art, an annular detector **110** (shown here as a two-stage multichannel plate) providing current gain and a collection anode **111** typically are mounted on the bottom of the charged particle column **102** as illustrated in FIG. **1**. To enhance collection of secondary particles, a collection grid **112**, supported by an inner ring **114** and an outer ring **116**, may be employed. A single voltage is applied to the collection grid **112** to draw secondary particles towards the grid **112** which is largely transparent to secondary particles that mostly pass through grid **112** and are subsequently collected by detector **110** and collection anode **111**. Detector **110** may comprise a multi-channel plate (MCP), in which case the signal current is collected on an anode **111**, as shown. Alternatively, detector **110** may comprise a PIN diode detector, a scintillator connected to a light pipe and photomultiplier tube (see FIG. **8**), or possibly other types of charged particle detector—in these cases, anode **111** may not be necessary, since the signal is derived by the detector **110** itself. Details of the detector **110** and anode design **111** are well-known in the art.

Due to the cosine emission pattern of the secondary particles, some particles **152** will be emitted too close to the axis of column **102** to be collected by grid **112**, and thus will pass up the bore of the charged particle column **102**, and will not be detected. Those secondary particles **118** which were emitted from target **108** at slightly larger angles than particles **152** pass through grid **112** to be collected near the center of detector **110**, as shown. A smaller portion of secondary particles **120** which are emitted at much larger angles pass through collection grid **112** much farther off-axis and are collected near the outer edge of detector **110**. It is well known in the art that many types of detectors, such as both multichannel plates, PIN diodes, and scintillators, demonstrate damage mechanisms which are functions of the total integrated signal current into each area of the detector. Thus, for an MCP detector **110**, the region near the central hole (required to allow passage of the primary beam **104** to the target **108**) will be damaged before the outer regions of the MCP **110**. A similar situation applies to PIN diodes and scintillators. In addition to damage, detectors may also become contaminated with polymerized hydrocarbons from a poor vacuum between the target and detector—note that this may occur due to beam-target interactions, even in cases where the base vacuum level would have been adequate to prevent contamination. In either case, the lifetime of an entire detector is determined by when a certain level of damage and/or contamination has occurred anywhere on the detector, even if the remainder of the detector is not yet damaged and/or contaminated to an unusable degree. The lifetime of detector **110** in the prior art configuration illustrated in FIG. **1** may be substantially reduced compared with the case where secondary particles were more uniformly distributed over the detector **110** surface.

FIG. **1**B shows a portion of the prior art charged particle detector **100** from FIG. **1**A. Detector **110** is shown in a view looking up at the input signal collection surface (lower surface of detector **110** in FIG. **1**A). The concentration of the input signal current near the center of detector **110** is illustrated using progressively-heavier cross-hatched shading from the edge to the center of detector **110**. Three regions **140**, **142**, and **144**, of the detector **110** at the center, middle, and edge, respectively, are indicated by the circles with arrows to the corresponding graphs, below.

Starting at the inner edge **140** of the central hole in detector **110** (where ring **114** in FIG. **1**A is attached), graph **170** is a plot of the local signal gain **172** as a function of the time-integral **171** of the output (i.e., amplified) signal current from region **140** over the lifetime of detector **110**. As shown, gain curve **174** has an initial high level **176**, which is maintained over a certain total time-integral of output signal current (i.e., to a certain total output signal charge), then gain curve **174** drops to a lower level **178** at the right of graph **170**. Because the input signal current at region **140** is relatively high, the cross-hatched shading representing the time-integral of the output signal current extends to line **179**, nearly at the point at which the gain curve **174** will start to drop. Thus, the useful lifetime of detector **110** is nearly over.

At the middle region **142** in detector **110**, the input signal current is at a medium level. Graph **160** is a plot of the local signal gain **162** as a function of the time-integral **161** of the output signal current from region **142** over the lifetime of detector **110**. As shown, gain curve **164** has an initial high level **166**, which is maintained over a certain total time-integral of output signal current, then gain curve **164** drops to a lower level **168** at the right of graph **160**. The key difference from graph **170** is that the cross-hatched shading extends only to line **169**, a substantial distance from the point at which the gain **164** will drop—thus, at region **142**, detector **110** still has a substantial useful lifetime remaining. Of course, since the detector lifetime depends on all areas being usable, this localized residual lifetime of region **142** cannot be used due to region **140** having essentially no residual lifetime.

Similar considerations apply at the outer region **144** of detector **110**—where graph **150** is a plot of the local signal gain **152** as a function of the time-integral **151** of the output signal current from region **144** over the lifetime of detector **110**. As shown, the gain curve **154** has an initial high level **156**, which is maintained over a certain total time-integral of output signal current, then gain curve **154** drops to a lower level **158** at the right of graph **150**. Because the input signal current at region **144** is relatively low compared to the input signal currents at regions **142** and **140**, the edge **159** of the cross-hatched area is farther to the left, showing that most of the detector lifetime at region **144** at the edge of detector **110** has not been used by the time area **140** is close to becoming unusable. Comparison of graphs **150**, **160**, and **170** illustrates how the lifetime of detector **110** may be substantially reduced when the input signal currents between regions **140**, **142** and **144** are unequal.

FIG. **2**A shows a first embodiment **200** of the invention, comprising a multiplicity of annular collection grids **222**, **224**, **226**, and **228**, supported by an inner ring **214** and an outer ring **216**. The exact number of grids would be determined by the degree of electric field uniformity desired. The number of grids is preferably between 2 and about 20, more preferably between 2 and 8, and most preferably between 3 and 5. A charged particle column **202** focuses a charged particle beam **204** onto a location **206** on the surface of a target **208**. Due to the impact of the beam **204** with the target **208**, secondary particles may be emitted from the target **208**. FIGS. **6** and **7**, below, discuss two electrical circuits which may be used to apply differing bias voltages to the inner ring **214**, annular grids **222**, **224**, **226**, and **228**, as well as the outer ring **216**. The bias voltages are set to create an electric field which pulls secondary particles away from the symmetry axis of the column **202**, detector **210** and collection anode **211**. Thus, under the influence of the electric field, secondary particles **232** pass through grid **222**, secondary particles **234** pass through grid **224**, secondary particles **236** pass through grid **226**, and secondary particles **238** pass through grid **228**. Secondary particles **252** which are emitted near the symmetry axis are not collected. Comparison of FIGS. **1**A and **2**A shows that the radial distribution of secondary particles entering the grids **222**, **224**, **226**, and **228**, is now less concentrated near the symmetry axis of detector **210** and collection anode **211**. The net result is that now a larger fraction of the collection area of detector **210** is utilized effectively in providing signal gain, potentially reducing or eliminating signal gain saturation effects as discussed above. Because the distribution of current into detector **210** is more uniform, the damage and/or contamination mechanisms discussed in FIG. **1**A will also occur more uniformly over the entire collection area of detector **210**. The lifetime of detector **210** with respect to damage and/or contamination should thus be increased, reducing maintenance costs for the system comprising this detector system **200**.

FIG. **2**B shows a portion of the charged particle detector **200** of a first embodiment of the present invention from FIG. **2**A. Detector **210** is shown in a view looking up at the input signal collection surface (lower surface of detector **210** in FIG. **2**A). The relative uniformity of the input signal current across the collection area of detector **210** enabled by the present invention is illustrated using uniform cross-hatched shading across the full collection area of detector **110** (compare with FIG. **1**B). Three regions **240**, **242**, and **244**, of the detector **210** at the center, middle and edge, respectively, are highlighted.

Starting at the inner edge **240** of the central hole in detector **210** (where ring **214** in FIG. **2**A is attached), graph **270** is a plot of the local signal gain **272** as a function of the time-integral **271** of the output (i.e., amplified) signal current from region **240** over the lifetime of detector **210**. As shown, gain curve **274** has an initial high level **276**, which is maintained over a certain total time-integral of output signal current (i.e., to a certain total output signal charge), then gain curve **274** drops to a lower level **278** at the right of graph **270**. Because the input signal current at region **240** is lower than for the comparable graph **170** in FIG. **1**B, the cross-hatched shading representing the time-integral of the output signal current extends to line **279**, which is only about half of the way to the point at which the gain curve **274** will start to drop. Thus, about half of the useful lifetime of detector **210** remains, in contrast with the case in FIG. **1**B.

At the middle region **242** in detector **210**, the input signal current is at roughly the same level as for area **240**. Graph **260** is a plot of the local signal gain **262** as a function of the time-integral **261** of the output signal current from region **242** over the lifetime of detector **210**. As shown, gain curve **264** has an initial high level **266**, which is maintained over a certain total time-integral of output signal current, then gain curve **264** drops to a lower level **268** at the right of graph **260**. Note that the cross-hatched shading extends to line **269**, at roughly the same position along axis **261** as line **279** is along axis **271** in graph **270**—thus, at region **242**, detector **210** still has about the same useful lifetime remaining as at region **240**.

Similar considerations apply at the outer region **244** of detector **210**—where graph **250** is a plot of the local signal gain **252** as a function of the time-integral **251** of the output (signal current from region **244** over the lifetime of the detector **210**. As shown, gain curve **254** has an initial high level **256**, which is maintained over a certain total time-integral of output signal current, then gain curve **254** drops to a lower level **258** at the right of graph **250**. Because the input signal current at region **244** is similar to the input signal currents at regions **240** and **242**, the edge **259** of the cross-hatched area is roughly at the same location along axis **251** as lines **269** and **279** are along axes **261** and **271**, respectively. Comparison of the cross-hatched areas in graphs **250**, **260**, and **270** illustrates how the lifetime of detector **210** may be substantially increased when the input signal currents between regions **240**, **242** and **244** are equalized by the present invention.

FIG. **3** shows a second embodiment **300** of the invention, comprising a single resistive annular collection grid **312**, supported by an inner ring **314** and an outer ring **316**. A charged particle column **302** focuses a charged particle beam **304** onto a location **306** on the surface of a target **308**. As in FIGS. **1** and **2**, the impact of the charged particle beam **304** with the target **308** may induce the emission of secondary particles. The first embodiment in FIG. **2** utilized a series of concentric annular grids to produce an electric field to draw secondary particles away from the axis and out to regions of the detector which would normally receive lower secondary particle currents. The second embodiment of the present invention illustrated in FIG. **3** utilizes a resistive grid **312** upon which a radial voltage gradient is applied arising from a voltage difference between the inner ring **314** and the outer ring **316**. In the case of secondary electron collection by detector **310**, the radial force vector **324** would correspond to a more positive voltage on the outer ring **316** and a less positive voltage on the inner ring **314**. In the case of (positive) secondary ion collection by detector **310**, the relative voltages on the inner ring **314** and outer ring **316** would be reversed. Since some portion of the secondary particles (either electrons or ions) will strike the resistive grid **312**, it is necessary to ensure that the resulting current in grid **312** does not affect the radial voltage gradient desired in grid **312** to establish the correct electric field needed to equalize the radial distribution of secondary particles reaching the detector **310** and collection anode **311**. This is a similar situation to that found in photomultiplier tubes (PMTs), where typically the current in the resistor chain used to generate the voltages on the dynodes is specified to be at least ten times higher than the largest internal currents within the PMT. When this condition is not met, the voltage distribution within the resistive grid **312** may not produce the desired distribution of trajectories **332**, **334**, **336**, and **338** passing through resistive grid **312** shown in FIG. **3**. Detector **310** (shown here as an annular two-stage multichannel plate providing current gain) and the collection anode **311** typically are mounted on the bottom of the charged particle column **302**. As in FIGS. **1** and **2**, a small portion **352** of secondary particles emitted near the symmetry axis of the column **302**, detector **310**, and collection anode **311**, will pass up the bore of column **302** and will not be detected.

FIG. **4** shows a third embodiment **400** of the invention, comprising a multiplicity of deflector electrodes **424** for attracting secondary particles away from the symmetry axis of the column **404**, detector **410**, and collection anode **411**. A charged particle column **402** focuses a charged particle beam **404** onto a location **406** on the surface of a target **408**. As in FIGS. **1** through **3**, the impact of the charged particle beam **404** with the target **408** may induce the emission of secondary particles which may be secondary electrons and/or secondary ions. A collection grid **412** is supported by an inner ring **414** and an outer ring **416**. In one version of the third embodiment, the inner ring **414**, grid **412** and outer ring **416** may have the same voltage—in this case, the deflector electrodes **424** generate a more uniform distribution of secondary particles at detector **510** and collection anode **511**. In another version of the third embodiment, the multiplicity of grids of the first embodiment may be substituted for conductive grid **412**, thereby enabling the generation of a radial electric field by means of both deflector electrodes **424** and a multiplicity of concentric annular collection grids such as grids **222**, **224**, **226**, and **228** in FIG. **2**. In still another version of the third embodiment, the resistive collection grid **312** of the second embodiment (see FIG. **3**) may be substituted for conductive grid **412**, thereby enabling the generation of a radial electric field by means of both the added deflector electrodes **424** and the resistive grid **312**. In the case of secondary electron collection, deflector electrodes **424** would have a positive bias applied to attract the secondary electrons radially outwards as shown by force vectors **460**, and hence through grid **412** and onto detector **410** at a larger radius than would otherwise have been the case. For (positive) secondary ions, a negative bias would be applied to deflector electrodes **424**, again making force vectors **460** point radially outwards. Secondary particles **452** which are emitted near the symmetry axis are not collected. Detector **410** (shown here as an annular two-stage multichannel plate providing current gain) and the collection anode **411** typically are mounted on the bottom of the charged particle column **402**.

FIG. **5** shows a fourth embodiment **500** of the invention, comprising an off-axis charged particle detector with a multiplicity of collection grids **522**, **524**, **526**, and **528**, supported by an inner electrode **514** and an outer electrode **516**—details of the mechanical support for grids **522**, **524**, **526**, and **528** are not part of the present invention and are not shown. Note that there is no circular symmetry assumed or required for this fourth embodiment. A charged particle column **502** focuses a charged particle beam **504** onto a location **506** on the surface of a target **508**. As in FIGS. **1** through **4**, due to the impact of the beam **504** with the target **508**, secondary particles may be emitted from the target **508**. The differing bias voltages on the grids **522**, **524**, **526**, and **528**, are adjusted to create an electric field which pulls secondary particles away from the symmetry axis of the column **502** (although the detector has no required symmetry for this embodiment, the column **502** will still typically retain circular symmetry with respect to the beam-forming optics)—toward the right of FIG. **5**, in this example. Thus, under the influence of the electric field, secondary particles **532** pass through grid **522**, secondary particles **534** pass through grid **524**, secondary particles **536** pass through grid **526**, and secondary particles **538** pass through grid **528**. The same considerations apply to this non-circularly symmetric detector system as applied in FIGS. **2** through **4** for the circularly-symmetric detectors of the first three embodiments—the voltages on grids **522**, **524**, **526**, and **528** may be adjusted to spread out the distribution of secondary particles entering detector **510** and collection anode **511**, thereby making any damage and/or contamination mechanisms also more uniform. Secondary particles **552** which are emitted near the symmetry axis are not collected. Detector **510** (shown here as a two-stage multichannel plate providing current gain) and the collection anode **511** typically are mounted on the bottom of the charged particle column **502**.

FIG. **6** shows an electrical schematic diagram **600** for a first biasing circuit for a multiplicity of grids **622**, **624**, **626**, and **628**, supported by an inner electrode **614** (corresponding to inner ring **214** in FIG. **2** or inner electrode **514** in FIG. **5**) and an outer electrode **616** (corresponding to outer ring **216** in FIG. **2** or outer electrode **516** in FIG. **5**). Circuit **600** is applicable to the detector systems illustrated in FIGS. **2** and **5**, and would also be applicable if the detector system in FIG. **4** were combined with the segmented grid structures from FIG. **2**. Detector **610** may represent one side of an annular detector such as detector **210** in FIG. **2**, or an off-axis detector such as detector **510** in FIG. **5**. In either case, the symmetry axis **640** represents the optical axis for the charged particle column generating the secondary particles entering detector **610** and collection anode **611**. A dc power supply **602** is connected through a first wire **604** to electrode **614** and through a second wire **606** to electrode **616**. The voltage bias connections for the detector **610** and collection anode **611** are not part of the present invention and are not shown. The collection grid assembly comprises four grids **622**, **624**, **626**, and **628**, connected in series between electrode **614** and electrode **616** by resistors **632**, **634**, **636**, **638** and **640**. The exact number of grids would be determined by the degree of electric field uniformity desired and is not part of the present invention. The same considerations which were discussed in FIG. **3** apply here—it is preferable to ensure that the current flowing from dc power supply **602** through electrodes **614** and **616**, grids **622**, **624**, **626**, and **628**, and resistors **632**, **634**, **636**, **638**, and **640** is substantially higher (typically ten times) than any anticipated secondary particle currents which might strike any of the grids **622**, **624**, **626**, and **628** to ensure that there is no “current loading”, causing unwanted deviations in the electric field distribution between the target (not shown) and detector **610**. A potential problem with circuit **600** is the requirement that the resistors **634**, **636**, and **638** (but not necessarily resistors **632** and **640**) be mounted between the successive grids to which they attach—this may be undesirable since resistors **634**, **636** and **638** would then be exposed to a portion of the secondary particle flux from the target. This may cause charging of the exterior surfaces of the resistors which could perturb the desired electric field distribution. It is also possible that the secondary particle flux could damage the resistors, causing incorrect resistance values or even shorts between neighboring collector grids.

FIG. **7** shows an electrical schematic diagram **700** for a second biasing circuit for a multiplicity of grids **722**, **724**, **726**, and **728**, supported by an inner electrode **714** (corresponding to inner ring **214** in FIG. **2**) and an outer electrode **716** (corresponding to outer ring **216** in FIG. **2**). Circuit **700** is applicable to the detector system illustrated in FIG. **2**, and would also be applicable if the detector system in FIG. **4** were combined with the segmented grid structures from FIG. **2**. The off-axis detector system illustrated in FIG. **5** may not need circuit **700** since a non-circularly symmetric detector system has room for the grading resistors without the need for the shielded cable configuration illustrated here. Detector **710** may represent one side of an annular detector such as detector **210** in FIG. **2**. The symmetry axis **740** represents the optical axis for the charged particle column generating the secondary particles entering detector **710** and collection anode **711**. A dc power supply **702** is connected through a first wire **704** to electrode **714** and through a second wire **706** to electrode **716**. The voltage bias connections for the detector **710** and collection anode **711** are not part of the present invention and are not shown. The collection grid assembly comprises four grids **722**, **724**, **726**, and **728**, connected in series between electrode **714** and electrode **716** by resistors **732**, **734**, **736**, **738** and **740**. The exact number of grids would be determined by the degree of electric field uniformity desired and is not part of the present invention. Note that electrically, FIG. **7** is the same as FIG. **6**—the difference is the physical locations for the five voltage divider resistors **732**, **734**, **736**, **738**, and **740** and the addition of coaxial shields **752**, **754**, **756**, **758**, **760**, and **762**. As discussed in FIG. **6**, it may be problematic to locate the voltage divider resistors between the successive grids in the grid assembly. FIG. **7** illustrates an alternative architecture in which the resistors **732**, **734**, **736**, **738**, and **740** may be located outside the grid assembly, thereby avoiding the problems discussed in FIG. **6**. However, simply connecting unshielded wires to each of the grids would present a new problem—since these wires necessarily must extend outwards from each annular grid, there will be overlaps between the wires from inner annular grids (such as **722**, **724** and **726**) and all the annular grids which are outside of the particular annular grid being connected to (such as grids **724**, **726**, and **728** for grid **722**). One potential solution to this problem is illustrated here—the wire connecting to the inner annular grid **722** passes through a series of coaxial shields **752**, **754**, and **756**, and then connects to resistors **732** and **734** in the voltage divider comprising resistors **732**, **734**, **736**, **738** and **740**, connected between the output wires **704** and **706** of dc power supply **702**. Similarly, the wire connecting to annular grid **724** passes through coaxial shields **758** and **760**, and then connects to resistors **734** and **736** in the voltage divider. In the same way, the wire from grid **726** passes through coaxial shield **762** and then connects to resistors **736** and **738** in the voltage divider. The wire connecting to the outer annular grid **728** can directly connect to resistors **738** and **740** in the voltage divider. The electrical connection between annular grid **722** and inner ring **714** is completed outside through resistor **732** as shown. All of the shields **752**, **754**, **756**, **758**, **760**, and **762** represent essentially short sections of coaxial cable. The outer conductors of each shield are electrically (and, optionally, also mechanically) connected to the respective grids (e.g., shield **752** connected to grid **724**) so that as each wire passes across an annular grid, there is no electric field induced by the center wire which is, of course, at a different voltage since each grid voltage has been set to a desired value for optimum charged particle collection. The short sections of wire between successive shields (e.g., between shields **752** and **754**) will probably need to be stripped of the coaxial cable insulation (thus leaving a short section of the center wire exposed, e.g., the wire from grid **722** being exposed between shields **752** and **754**) to avoid possible charging effects which might occur due to secondary particles collecting on exposed insulation.

FIG. **8** shows a version **800** of a first embodiment of the invention, comprising a scintillator **860**, light pipe **862** and photomultiplier **864**, as well as a multiplicity of annular collection grids **822**, **824**, **826**, and **828**, supported by an inner ring **814** and an outer ring **816**—details of the mechanical support for grids **822**, **824**, **826**, and **828** are not part of the present invention and are not shown. A charged particle column **802** focuses a charged particle beam **804** onto a location **806** on the surface of a target **808**. FIGS. **6** and **7**, above, discuss two electrical circuits which may be used to apply differing bias voltages to the inner ring **814**, annular grids **822**, **824**, **826**, and **828**, as well as the outer ring **816**. Secondary particles **832** pass through grid **822**, secondary particles **834** pass through grid **824**, secondary particles **836** pass through grid **826**, and secondary particles **838** pass through grid **828**. The key difference in FIG. **8** relative to FIG. **2** is the substitution of a scintillator **860**, light pipe **862**, and photomultiplier **864** in place of the multichannel plate (MCP) detector **210** and collection anode **211** shown in FIG. **2**. Like multichannel plates, scintillators also exhibit long-term damage resulting from changes in the scintillator molecular or crystal structure as a result of bombardment by charged particles. Scintillators may also become contaminated by polymerized hydrocarbons, etc. Thus, the same damage and/or contamination issues apply here as were discussed above. Scintillator **860** emits light **866** when bombarded by energetic charged particles **832**, **834**, **836**, and **838**. Light **866** passes through, and undergoes total internal reflection at the walls of, light pipe **862**, then passing into photomultiplier **864**. Secondary particles **852** which are emitted near the symmetry axis are not collected.

A number of combinations of different detector types and grid geometries have been illustrated in FIGS. **2** through **5**, and **8**. Table I lists a number of detector system configurations—other detector types and electrical biasing circuits are also possible within the scope of the present invention

TABLE I

Different detector system configurations and the corresponding detectors and electrical connections.

Detector System Configuration	Types of Detectors: MCP	Types of Detectors: PIN Diode	Types of Detectors: Scintillator + PMT	Electrical Connections: FIG. 6	Electrical Connections: FIG. 7
Embodiment 1 - Concentric Annular Grids	Yes	Yes	Yes	Yes	Yes
Embodiment 2 - Annular Resistive Grid	Yes	Yes	Yes	Yes	Yes
Embodiment 3 - Added Deflector Electrodes	Yes	Yes	Yes	Yes	Yes
Embodiments 1 + 3 - Annular Grids + Deflector Electrodes	Yes	Yes	Yes	Yes	Yes
Embodiments 2 + 3 - Resistive Grid + Deflector Electrodes	Yes	Yes	Yes	Yes	Yes
Embodiment 1 - Multiplicity of Grids (No circular Symmetry)	Yes	Yes	Yes	Yes	Probably Not Needed
Embodiment 2 - Resistive Grid (No circular Symmetry)	Yes	Yes	Yes	Yes	Probably Not Needed
Embodiment 3 - Added Deflector Electrodes (No circular Symmetry)	Yes	Yes	Yes	Yes	Probably Not Needed
Embodiments 1 + 3 - Grids + Deflector Electrodes (No Circular Symmetry)	Yes	Yes	Yes	Yes	Probably Not Needed
Embodiments 2 + 3 - Resistive Grid + Deflector Electrodes (No Circular Symmetry)	Yes	Yes	Yes	Yes	Probably Not Needed

The various embodiments of the present invention discussed in FIGS. **2** through **5** apply to non-imaging detectors, i.e., where the imaging signal arriving at the detector and then conveyed to the collection anode (if the detector is a multichannel plate) carries no positional information. The entire detector in these examples generated a single imaging signal, no matter where the secondary particle (carrying the imaging information) strikes the detector and collection anode surface. Thus, the design of the multiplicity of grids, the resistive grid, or the deflector electrodes could be optimized solely for more uniform current into the detector and collection anode. Embodiments of the present invention are also applicable for those alternative situations in which the imaging particles carry both intensity and positional information. In these cases, we are not free to ignore where on the detector the secondary particle strikes, and the collection anode will generally comprise multiple individual detectors, each collecting (amplified) current from a small region of the multichannel plate. This contrasts with the detector system **200** in FIG. **2**, where a single collection anode **211** receives all the amplified signal current generated by detector **210**, regardless of where on detector **210** the original secondary particle arrived. FIGS. **9** and **10** discuss two exemplary cases of the application of the present invention to imaging detectors—other cases also fall within the scope of the present invention.

FIG. **9** shows an application of the present invention to a detector system **900** of a transmission electron microscope (TEM). In a TEM, a condenser and projector optics system projects a beam **902** of primary electrons onto the surface of a sample **904** to be imaged. As shown in FIG. **9**, electrons **906** and **907** are scattered from various locations within sample **904**. For simplicity, electrons **906** and **907** represent particular electron trajectories which are deflected within sample **904** at angles such that electrons **906** and **907** pass undeflected through lens **908**, then travel downwards to the detector system comprising multiple annular grids (including outermost grid **932** and innermost grid **933**) supported by ring electrode **930**, and then into a two-stage multichannel plate **934**, and finally to collection anode assembly **936**, comprising multiple collection elements (including elements **914** and **924**). Not all electrons emerging from sample **904** pass through the center of lens **908**—electrons **904** and **942** illustrate a typical envelope of scattered electrons which would pass through objective lens **908**, then being focused by lens **908** onto annular grid **932**. Due to the voltages applied to the annular grids, an outward radial force **950** on the secondary particles between lens **908** and the multiple annular grids is generated. As an example, trajectory **906** emerging from the bottom of sample **904** passes through lens **908**, becoming trajectory **910** which is then deflected outwards by force **950** to become trajectory **912** entering the outermost annular grid **932**. Trajectories **940** and **942** emerging from the same location on sample **904** become trajectories **944** and **946**, respectively, after focusing by lens **908**, arriving at approximately the same location on grid **932** as trajectory **912**. After current amplification by the two-stage multichannel plate **934**, a current proportional to the current passing through grid **932** is collected on element **914** of the collection anode assembly **936**—note that the positional information carried by the input signal passing through grid **932** is preserved by using a collection anode assembly **936**, instead of a single collector anode (such as collector anode **211** in FIG. **2**).

Electron trajectory **907**, much nearer the axis, passes through lens **908**, becoming trajectory **920** which is then deflected outward by force vector **950** to become trajectory **922** entering the innermost annular grid **933**, and then, after current amplification, the signal current is collected by element **924** of collection anode assembly **936**. Again, the positional information in the input signal reaching the grid has been preserved (it has just been stretched radially outwards in a 1:1 mapping that can be calibrated or calculated in advance). FIG. **9** shows an imaging detector embodiment of the present invention—in the absence of the segmented collection grid assembly, the electron trajectories reaching the multichannel plate **934** and collection anode assembly **936** would be more concentrated near the center of the MCP **934**. This can be seen by extrapolating trajectories **910** and **920** without radial outward force vectors **950** all the way to the entrance plane of the grid assembly. Clearly, then, the imaging signals generated from collection anode assembly **936** would arise from a smaller number of collection elements near element **924**, and elements **914** at the outer edge of the collection anode assembly would not receive any current at all. Two potential advantages of some embodiments of the present invention for imaging detector applications can now be seen:

1) The damage and/or contamination of the detector **934** will be more uniform, leading to longer detector lifetimes—this is the same benefit as was found above for non-imaging detectors.
2) The imaging resolution is potentially increased, since now a larger number of collection elements are used (such as outer element **914**) than would be the case for a beam which was more concentrated near the center of the detector assembly **934** and collection anode assembly **936**.

FIG. **10** shows an embodiment of the present invention applied to a detector system **1000** of a scanning transmission electron microscope (STEM). In a STEM, a beam **1002** of electrons is focused onto the surface of a sample **1004** and scanned in a raster pattern by a deflection system to generate an image, similar to the imaging process in a scanning electron microscope (SEM). As the electron beam **1002** passes through the sample **1004**, electrons in the beam are scattered by nuclei in the sample **1004** (leading to "elastic scattering") and electrons in the sample **1004** (leading to "inelastic scattering"). As an example, electrons **1008** are scattered at larger angles, characteristic of elastically-scattered electrons. Electrons **1011** have small scattering angles, and may be inelastically-scattered. Both types of electrons contain important structural and compositional information about the sample **1004**, and it is preferred to configure the detector system **1000** to simultaneously collect both imaging signals. It is well known in the art that the ratio of the elastic signal to the inelastic signal is proportional to the local atomic number of the sample. Typically, the STEM detector optics will comprise a lens **1010** below the sample **1004** (often this lens is formed by that portion of the objective lens magnetic field which is below the sample plane, but additional lenses may also contribute to the net focusing effect illustrated by the single lens **1010** in FIG. **10**). Off-axis trajectory **1008** is focused by lens **1010**, resulting in trajectory **1009**. Similarly, near-axis trajectory **1011** is focused by lens **1010**, resulting in trajectory **1012** (aberrations in lens **1010** are neglected here). In the absence of the radial outward forces **1050**, trajectories **1009** and **1012** would reach the collection grid near the axis (at the center). With radial outward forces **1050** generated by the voltages on the annular grids (such as grids **1032** and **1033**) in the collection grid assembly, the input signal currents reaching the two-stage multichannel plate **1034** and then the collection anode assembly **1036** fill a larger portion of the respective available detector and collection areas. For example, trajectory **1009** is deflected outwards, becoming trajectory **1014** which passes through outermost annular grid **1032**, and then the corresponding (amplified) current reaches outermost collection element **1016**. Similarly, trajectory **1012** is deflected outwards, becoming trajectory **1024** which passes through innermost annular grid **1033**, and then the corresponding (amplified) current reaches innermost collection element **1026**. Again, note that the scattering angle information carried by signals **1008** and **1011** is preserved, along with the image intensity information carried in the relative currents in signals **1008** and **1011**. As in all scanning systems (such as SEMs and STEMs), positional information is in the time that the signal is collected, being correlated with the (known) position of the beam during raster scanning. The same two benefits discussed for FIG. **9** also apply here—increased detector lifetime and potentially improved imaging resolution.

With a small modification, FIG. **10** can also apply to the case of electron diffraction in the STEM. If the primary beam **1002** is made nearly parallel and illuminates a somewhat larger area of the sample **1004**, while not being raster scanned across sample **1004**, it is possible to acquire an electron diffraction image—in this case, the various trajectories **1008** and **1010** would correspond to different scattering angles. All other considerations discussed above would apply to this example, as well.

Although embodiments of the present invention and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made to the embodiments described herein without departing from the spirit and scope of the invention as defined by the appended claims. The voltage source for the grids may come from a single power source and use a voltage divider, separate power sources can be used for each grid, or some combination of voltage drivers and power sources may be used. While the examples provide an electric field to alter the trajectories of the secondary particles, a magnetic field could be used, although the effect of the magnetic field on the primary beam must be considered. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

I claim as follows:

1. A charged particle system, comprising:

a charged particle column for focusing a primary charged particle beam onto the surface of a target, wherein the impact of the charged particle beam with the target induces emission of secondary particles from the target;

a charged particle detector assembly including:

a detector for producing an electrical signal corresponding to the number of charged particles impacting the detector;

at least one grid, positioned between the charged particle detector and the surface of the target for causing charged particles to move from the target to the detector; and

a source of a field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector by spreading the impinging particles more evenly over the detector, thereby prolonging the useful life of the charged particle detector.

2. The charged particle system of claim **1** wherein:

the at least one grid comprises at least two grids; and

the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises different potentials on the different ones of the at least two grids.

3. The charged particle system of claim **1** wherein:

the at least one grid comprises at least one resistive grid; and

the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises different potentials on the different parts of the at least one resistive grid.

4. The charged particle system of claim **1** wherein the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises deflector electrodes positioned between the at least one grid and the target.

5. The charged particle system of claim **1** wherein the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises a source of a field that deflects the secondary charged particles away from the axis of the charged particle column.

6. The charged particle system of claim **1** wherein the charged particle detector comprises a multichannel plate and a collection anode; a PIN diode; or a scintillator-photomultiplier with a light optical coupling means positioned between the scintillator and the photomultiplier, configured to transmit light emitted by the scintillator into the photomultiplier.

7. The charged particle system of claim **1** wherein the charged particle beam is an electron beam or a focused ion beam, and wherein the voltages on the at least one grid and the voltages on the charged particle detector are configured to collect secondary electrons.

8. The charged particle system of claim **1** wherein the charged particle beam is a focused ion beam, and wherein the voltages on the at least one grid and the voltages on the charged particle detector are configured to collect secondary ions.

9. The charged particle system of claim **1** wherein the charged particle beam is a focused ion beam, and wherein the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector is configured to collect secondary ions.

10. The charged particle system of claim **1** in which the source of the field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector deflects the secondary particles in a manner that maintains the relative positions of the secondary particles from the optical axis of the column.

11. A method of reducing the rate of damage or contamination in a secondary particle detector in a charged particle system, comprising:

providing a charged particle column to focus a charged particle beam onto the surface of a target, wherein the impact of the charged particle beam with the target induces the emission of secondary particles from the target;

providing a secondary particle detector to collect a portion of the secondary particles emitted from the target;

providing a field to deflect the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector by spreading the impinging particles more evenly over the detector, thereby prolonging the useful life of the charged particle detector.

12. The method of claim **11** further comprising providing at least one grid to accelerate secondary particles from the surface toward the secondary particle detector.

13. The method of claim **12**, wherein providing at least one grid includes providing a resistive grid, and further comprising a first voltage to one portion of the resistive grid and a second voltage to a second portion of the resistive grid, wherein the first and second voltages are unequal.

14. The method of claim **12** wherein:

providing at least one grid includes providing two grids; and

providing a field to deflect the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises providing different potentials on the different ones of the at least two grids.

15. The method of claim **12** wherein:

providing at least one grid includes providing at least one resistive grid; and

providing a field to deflect the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises providing different potentials on the different parts of the at least one resistive grid.

16. The method of claim **12** wherein providing a field to deflect the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises providing deflector electrodes positioned between the at least one grid and the target.

17. The method of claim **11** further in which providing a secondary particle detector includes providing a secondary particle detector between the column and the target.

18. The method of claim **11** wherein providing a field to deflect the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector comprises providing a field that deflects the secondary particles away from the axis of the charged particle column.

19. The method of claim **11** wherein providing a secondary charged particle detector comprises providing a multichannel plate and a collection anode; a PIN diode; or a scintillator-photomultiplier with a light optical coupling means positioned between the scintillator and the photomultiplier, configured to transmit light emitted by the scintillator into the photomultiplier.

20. The method of claim **11** wherein providing a charged particle column includes providing an electron beam or a focused ion beam, and wherein the secondary particle collector collects secondary electrons.

21. The method of claim **11** wherein providing a charged particle column includes providing a focused ion beam, and wherein the secondary particle collector collects secondary ions.

22. A charged particle system, comprising:

a charged particle column for focusing a primary charged particle beam onto the surface of a target;

a charged particle detector assembly including:

a detector for producing an electrical signal corresponding to the number of charged particles impacting the detector;

at least one grid, positioned between the charged particle detector and the surface of the target for causing charged particles to move from the target to the detector;

a source of a field that deflects the secondary charged particles to reduce the maximum current density of the charged particles impinging on the charged particle detector by spreading the impinging particles more evenly over the detector, thereby prolonging the useful life of the charged particle detector.

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